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[redacted] 49 page report entitled Problem of Formation of Gas and Oil Accumulations in the Light of Source Rock Theory. This report was prepared by I O Brod, one of the leading Soviet petroleum geologists [redacted] The table of contents is as follows:

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PROBLEM OF FORMATION OF OIL AND GAS ACCUMULATIONS IN THE LIGHT OF SOURCE ROCK THEORY

by I.O.BROD

Fundamental distinctions in the conditions of formation of various categories of oil and gas accumulations

The conception of "oil and gas accumulations" is a collective term, as it embodies all categories of accumulations- from individual pools to groups of pools - both in the subsurface of separate areas as wellas within the large regional oil-and-gas-bearing zones (Brod, 1945, 1946 (1), (2), 1951, 1957 (4), Vassoevich and Ouspensky - 1954, Khain - 1954).

When examining closely the conditions of formation of oil accumulations, as far as single accumulations - pools is concerned - the principal task consists in elucidating how the hydrocarbon compounds composing the oil did get into a trap containing a pool.

The analysis of conditions leading to formation of an oil field embracing an aggregate of pools, which are buried in the subsurface of a common area and controlled in their formation by a single structural element, is far more complicated. In the process of analysis it is necessary, in the first instance, to reveal geological and hydrogeological environment of formation of structural bending of the rocks which caused

the emergence of numerous traps. Thereupon, it should be ascertained in what relationship are and were the traps at the time of their filling by the hydrocarbon compounds forming oil and gas pools. Practically the task comes to the study of conditions of migration and differentiation of mobil substances both in separate natural receptacles formed of reservoir rocks as well as in poorly permeable rocks dividing the reservoirs and forming the stratigraphic sequence of oil fields.

Analyzing conditions of formation of oil-and-gas accumulation zones embracing numerous oil and gas fields it is necessary to ascertain the sequence and correlation of geological, geochemical and hydrogeological processes leading to formation of numerous oil and gas accumulations regularly distributed in the subsurface of large areas of the earth's crust. During the last few years these questions have been thoroughly elucidated in several countries in numerous publications devoted to the regional hydrogeological environment and to the conditions of formation of separate oil fields and large oil and gas accumulation zones (Ignatovich - 1944, Brod - 1947, 1951, 1957 (4), Lintrop - 1951, Sukharev - 1953, Vassoevich and Ouspensky - 1954, Krems - 1954, Bakirov - 1955, Zalicker - 1949, Beeby-Thompson - 1950, Gussow - 1954, 1955, Hobson - 1956 and many others).

The problem of formation of oil and gas accumulation zones is closely related to the problem of origin of petroleum as the formation of these zones is the result of emergence and migration of substances entering as components in composition of petroleum in the earth's crust. Consequently, the study of

conditions of formation of zonal accumulations requires to reveal the regularities in occurence of oil and gas accumulations in the earth's crust.

On the regional productive formations and source rocks

It may be considered as an established fact that practically in all oil and gas basins of the Globe the oil and gas accumulations are related to the regionally spread productive series. The latter are known to be present in the deposits of different age and contain within the large areas either natural oil and gas seepages or oil and gas pools discovered by drilling ( ).

In the majority of regional productive series highly permeable rocks containing oils and gas are interbedded with shales and marles containing dispersed organic matter.

Widely distributed oil seepages related to the bituminous rocks are known in the Cambrian of the East-Siberian platform and in Canada though in considerably lesser degree; with the Cambrian of Appalachian trough are related gas accumulations.

Large oil and gas pools related to sandy marl and carbonate series of the Cambrian-Ordovician and in lesser degree to those of Silurian are known in the central part of the North-American platform . With similar lithological-stratigraphic complexes of the Lower Paleozoic are related bituminous rocks and oil and gas seepages of the Baltic regions of the Russian platform.

Still more widely are distributed oil and gas pools and seepages in a number of lithological and stratigraphic complexes of the Devonian and Carboniferous, and partly in Permian, in the central parts of the Russian and North-American platforms.

On the outskirts of the Russian, North-American and East-Siberian platforms and in several intermontane troughs of Eurasia, North and South America some lithological-stratigraphic complexes of the Jurassic and Cretaceous are regionally productive.

Oil and gas pools as well as oil and gas seepages in clastic carbonate complexes of Paleogene, Miocene and Pliocene are well known in piedmont depressions of the young folded structures and in a number of intermontane troughs of Eurasia, Oceania, North and South America. Oil pools in the same formations of deeply subsided southern part of the North-American platform are known as well.

The data on this question can be found in numerous summaries published during the last few years (Beeby-Thompson-1950, Landes - 1951, Russel - 1951, Illing - 1953, Levorsen - 1954, Brod & Eremenko - 1957 et al.).

In the earliest development of the oil industry at the close of nineteenth and in the beginning of twentieth century several researches were of the opinion that the oil is accumulated in reservoir rocks at the expense of migration of the substances composing the oil from silty sediments. The emergence of hydrocarbon compounds has been connected by the

above scientists with the transformation of organic substances dispersed among smallest mineral particles composing shales and marles. As concerns Caucasian petroliferous areas these ideas were formulated in the main in the works of N.I.Andrusov (1906) and G.M.Michailovsky (1906). The development of these ideas in other countries can be found in several special summaries (Hofer - 1888; Campbell - 1911; De Launey - 1913; Bogdanovitch - 1921; Blumer - 1922 et al.).

Later on the idea of relationship between the oil formation and the dispersed organic matter has been developped in the USSR on the basis of special investigations and a number of general conclusions in the publications of A.D.Arkhangelsky (1927), I.M.Gubkin (1932, 1940 (1) (2) and their numerous followers.

The status of this problem in other countries is elucidated in a series of fundamental works (Lilley - 1928; Krejci-Graf - 1930; Emmons - 1931; Stutzer - 1931; De Cizancourt - 1936; Macovei - 1938; Trask and Patnock - 1942 et al.).

A.D.Arkhangelsky (1927), basing on extensive collective study within several decades of the oil fields of Europe and America, noted that ... "for numerous oil fields it is well ascertained that the oil is related to those series of sedimentary rocks in whose composition are entering the rocks rich in organic matter of the petroleum type, so called bituminous shales, oil shales and limestones". And he stated further : "It is quite natural that many researchers have been confronted with the question : what are the conditions of formation of these bituminous rocks - conditions which might determine as well to a great extend the very process of the oil formation".

The series in which formation and accumulation of oil and gas are going on at the expense of transformation of dispersed organic matter contained therein, have been called by A.D.Arkhangelsky, I.M.Gubkin and their followers "primary oil-bearing series". The rocks containing dispersed organic matter which under favourable conditions can be transformed into petroleum were called "neftеproizvodiatschie" (oil producing) or "neftematerienskie" (source rocks). In the foreign literature these rocks are termed as follows : "source rocks" or "source beds" in English; "roches-mère" in French; "Ölmutter-gesteine" in German.

All important discoveries of the oil and gas zones in the Caucasus and on the Russian platform were made in the USSR on the basis of ascertained regularities in the occurence of oil and gas pools in regional petroliferous series.

All recent discoveries on the vast territory between the Volga and the Ural which allowed to increase by many times the oil production in the Soviet Union were made on the basis of ascertained regular relationship between oil and gas pools and certain lithological stratigraphic complexes of the Devonian and Carboniferous and partly Permian. The productivity of these complexes is connected with numerous and diverse structural zones (Brod - 1948; Bakirov - 1954; Trofimuk - 1955; Mirchink - 1956, 1957; Mustafinov - 1957 (1) & (2) et al.).

Taking into consideration the well studied relationship between oil and gas pools and definite intervals of Mesozoic-Cenozoic sequence and basing on lithological-stratigraphic

and tectonic regularities, we could outline for the territory adjacent to the Eastern Caucasus known and possible oil and gas accumulation zones corroborated by practice (subsequent drilling) (Brod - 1948, 1955; Alexine - 1956).

In the Volga-Ural region and in the region adjacent to the Caucasus the oil and gas pools are contained most frequently in natural reservoirs buried among the pelite rocks containing dispersed organic matter including bitumens kindred to the oils as regards to their composition. In these cases the oil-and-gas-bearing series can be considered at the same time as source rocks. In other cases we have to look for oil source material outside the productive formation. Thus, for exemple, the formation of "massive" oil and gas pools in the projections of dolomitic limestone series should be connected either with clay-marly strata mantling or underlying the above series or with those contacting same along the surface of facial substitution or unconformity (Brod, Tsaturov, Nesmeyanov - 1957 (3)).

In the continental deposits of the intermontane troughs of the Middle and Central Asia formed in oxidizing environment oil and gas seepages and pools are usually revealed in those cases where in the stratigraphic sequence there are present the strata of dark-coloured subaqueous pelite rocks which were deposited in recovery conditions.

Basing on a number of indications characterising source beds and on the correlation of source rocks with reservoir rocks, several authors made an attempt to segregate the

intervals of the sequence favourable for oil and gas accumulation both in various districts of the USSR (Oulianov - 1951, Ouspenskaya - 1952, Brod - 1952, 1955, 1957 (2) (3); Vassoevich and Ouspensky - 1954, Trofimuk - 1955, Maximov - 1955, Koniukhov 1956, Bakirov - 1957, Dvaly & Drobishev - 1957, Maimin - 1957, Mekhtiev - 1957, Mirchink - 1957, Geologicheskiy Sbornik No.1 - 1955, No.2 - 1956), as well as in other countries (Van Tuyl et al. - 1945, Wilcox - 1945, Gussow - 1955, Hobson - 1956 and many others).

In those regions where oil and gas accumulations are related to the series emerged in oxidizing conditions not allowing transformation of dispersed organic substances into bitumens particular attention is focused on the revelation of factors favorable for formation of oil and gas pools at the expense of migration ~~out of~~ from other possible source rocks. Thus, for example, in Azerbaidjan and Turkmenistan large oil and gas accumulations in Pliocene productive series of continental origin are related to the structural zones favourable for vertical migration of hydrocarbon compounds from more ancient source beds. (Gubkin - 1934, Gorin - 1940, Mechtiev - 1957 et al.). In this case emerge large oil and gas accumulation zones uniting numerous oil fields formed at the expense of migration of hydrocarbon compounds mainly from Miocen and Paleogene deposits underlying productive series.

Although some researchers (Kudriavtsev - 1951, 1955; Porfiriev - 1952, 1955) allege that the doctrine of the origin of petroleum from dispersed organic matter is presently at a deadlock, in fact during the last 10-15 years much more was

done for the development of this doctrine than during proceeding 60 years.

In the course of recent years it has been proved that dispersed organic substances kindred to petroleum are always contained in certain quantities practically in all argillaceous, shale-aleurite, sandy shale and marlaceous rocks formed in recovery environment (Eremenko, Maximov and Thostov - 1949; Strakhov & Rodionova - 1954, Theodorovich - 1952, 1954; Yurkevich - 1955, Brod & Levinson - 1955 (2); Sbornik "Proiskhojdenie nefti - 1955, Geologicheskiy Sbornik No.2 - 1956, Koniukhov - 1956 (1) and (2), Vassoevich - 1957, Maimin - 1957). The presence of bituminous substances kindred to petroleum has been revealed not only in the consolidated rocks, but also in recent and quaternary subaqueous sediments. The phenomena of transformation of these bituminous substances with the compacting of sediments into substances more and more kindred to petroleum hydrocarbons were ascertained at the same time (Weber - 1951, 1955; Smith - 1954, 1955).

The process of dissociation of organic substances is observed with the appearance of the new bituminous compounds emerging apparently at the expense of hydrogene disproportion (Brod and Mekhtiev - 1953; Geologicheskiy Sbornik No.1 - 1955, No.2 - 1956; Brod and Eremenko - 1957(1); Vassoevich - 1957). It may be surmised that in the process of compacting of pelite rocks there is going on a gradual metamorphisation of all components parts of the rocks and, in the first instance, a regular change of the main coaly part and also of bituminous part

accompanying the first. The conversion of coaly part of dispersed organic matter goes from ligniferous to carboniferous stage and so far as graphites. To all appearance this process is accompanied by the formation in subcapillary pores of the new bituminous compounds more and more rich in hydrogene content. The comparison of elementary and component composition of bituminous substances dispersed in subcapillary pores of pelite rocks with the petroleum saturating super-capillary pores of the reservoir rocks leads to the twofold conclusion : that there is a genetic resemblance, but that at the same time there is a number of distinctions depending on physico-chemical state of these substances. Therefore, the formation of petroleum as a substance possessing specific properties should be connected with the transition process from bituminous substances, which were in subcapillary pores in dispersed loose-bounded state, into the composite solution of hydrocarbons, resins and asphaltines in the water saturating reservoir rocks with subsequent accumulation of oil and gas in the traps (Fash - 1944; Brod - 1951, 1953 (2); 1957; Weber - 1955).

On the basis of ascertained regularities in the correlation of source rocks and reservoir rocks attempts have been made during the last few years to segregate the cycles of bitumen formation to which would correspond source rocks and regional productive lithological-stratigraphic complexes (Eremenko, Maximov, Thostov - 1949; Brod - 1951, Koniukhov - 1956 (1) (2)).

The analysis of regularities in the regional change of lithological composition and thicknesses of lithological-stratigraphic complexes favourable for oil and gas accumulation

provides an opportunity to dress in the first degree of approximation the maps of oil and gas possibilities for each and every of segregated complexes of the rocks, which was done, for exemple, in 1955 for the territory adjacent to the Eastern Caucasus (Brod - 1957 (3)).

In point of fact the overwhelming majority of the most important oil and gas accumulation zones discovered in the USSR, North and South America and recently in the Near and Middle East is connected with the regions of stable downwarping or subsidence of the earth's crust. In the sequence of these regions an important place is occupied by lithological-stratigraphic complexes which can be considered as source rock complexes (Howard - 1941; Pratt - 1944, 1947; Kaufmann - 1951, Brod - 1951 et al.).

The doctrine of source rocks and regional productive series born at the end of the last century had been gradually transforming into a harmonious theory. This theory does allow to make well-founded prognoses and carry out comparative estimation of oil and gas possibilities of large territories and separate oil and gas accumulation zones within their confines.

Regional conditions of oil and gas accumulation

Although the early studies devoted to the classification of oil and gas accumulations (Clapp 1910-1930; Gubkin - 1932 et al.) did not formulate distinctly the conception of "zonal occurrence of oil and gas accumulations", however their descriptions of separate groups of accumulations contain this conception already.

Up to the thirtieth of the 20th century the scientists have concentrated their attention and efforts to reveal the zonal relationship between numerous oil and gas accumulations and anticlinal zones.

A.I.Levorsen (1936) has formulated in a most distinct manner the conception of regular zonal occurence of numerous oil and gas traps on the flanks of large downwarped areas of the earth's crust. At the same time Levorsen has contrasted the structural factor of oil and gas accumulation to that of stratigraphic traps which emerge in case of lithological wedging out or unconfortable overlapping of productive series on their up-dip side.

The principal of division of productive zones into two genetic groups, viz.: structural and stratigraphic zones - has justified itself.

In 1937 I.M.Gubkin formulated a principle that for anticlinal zones to which are related numerous oil and gas fields the adjacent synclinal depressions serve as oil and gas collecting areas (Gubkin, 1940 (1)).

The conception of oil and gas accumulation zones introduced in petroleum literature (Brod, 1946) is indissolubly related to the conception of oil and gas collecting areas. Taking into consideration that in more downwarped areas of the earth's crust the pelite rocks are under a higher pressure if compared with uplifted areas, it should surmised that the differentiation of bituminous substances and educing of the most mobile particles into carrier beds should proceed in the direction from oil and gas collecting area towards oil and gas accumulation zones.

The bituminous substances migrating in subcapillary pores of pelite rocks as soon as reached highly permeable reservoir rocks enter into a close contact with water freely circulating in these rocks. In the process of differentiation of mobil substances in reservoir rocks there is going on the educing either of oil with gas of of pure gas with the formation of pools in separate traps. Numerous traps filled with oil and gas fields which form oil and gas are the parts of oil and gas accumulation zones (Brod, 1946, 1951, 1957).

The problem of regional differentiation of oil and gas inside the natural reservoirs and their accumulation in numerous traps has been throughly studied by W.C.Gussov, Canadian researcher. W.C.Gussow has worked out a harmonious theory of differential entrapment and accumulation. His theory grounds a number of regularities in the distribution in various traps of one and the same reservoir of pure gas pools, oil pools with gas cap and pure oil pools (Gussow, 1954). Some principles of this theory have been subjected to criticism on a special discussion, proceedings of which were published (Discussion, 1955). It has been argued that general regularities as emphasized by W.C.Gussow may take place only in a perfectly ideal case. Regular relations noted by the author are liable to be broken with the change of strata dip, increase or decrease of the depth of traps burial and with inflow of oil from depth along the faults and fractures. At the same time there was no disagreement that oil and gas pools emerge in the process of differentiation of the fluids at the time of their migration in the rocks of high permeability.

In the structural zones of oil and gas accumulation the feeding by hydrocarbon compounds usually takes place from two sides. The substances entering in composition of petroleum are migrating from synclinal depressions to the most uplifted parts of brachyanticlines and domes, which are the components of anticlinal zones, and are accumulated in the form of oil (gas) pools either in the arches of anticlines or in screened traps connected with their flanks or periclines.

The case proves to be somewhat different with the feeding by bituminous substances of stratigraphic zones of oil and gas accumulation embracing numerous traps emerged on homoclines or monoclines in connection with regional lithological wedging out or unconformity. Hydrocarbon compounds coming up the regional dip are accumulated in separate traps of the most varied shape, which are grouped along the wedging out border or unconformable overlapping of reservoir rocks. The feeding here is one-sided : the downdip parts of homo- and monoclines here adjacent serve as oil and gas collecting areas.

Numerous exemples of such conditions of oil and gas accumulation are quoted in Levorsen's publications (1936-1954) and many others. In the U.S.S.R. a similar zone of oil and gas accumulation in Maikop Oligocene petroliferous formation is well studied in Krasnodar region - in the western part of northern side of the Caucasus (Gubkin - 1912, 1940 (1); Helkwist - 1944, 1956, Oulianov - 1951). Large oil pools in the wedging out zones of lower strata of Pliocene productive series in Apsheron peninsula are likewise featured by one-sided hydrocarbon feeding (Mirchink - 1943, 1955; Gorin - 1946; Mekhtiev - 1949, 1957; Baba-Zade - 1956).

In order to elucidate the conditions of formation of oil and gas accumulation zones within the large territories it is necessary to ascertain the regularities in the occurence of these zones and oil and gas collecting areas related to them. American geologists (Woodruff - 1917, Schuchert - 1919, Lilley - 1928, Ver Wiebe - 1930) have introduced in literature in the first quarter of this century a term "oil and gas province" and less often "oil-bearing province" ("neftegasonosnaya provintsia")

N.U.Ouspenskaya (1947) defines this term as follows : "Under oil and gas province is understood a large territory of occurence of oil and gas accumulations possessing a unity of geological structure and geological history which is characterised by uniform facies and types of structural elements controlling bitumen formation and oil accumulation". Proceeding from such a definition N.U.Ouspenskaya considers as oil bearing provinces in one case - depressions of different age, in other case - large arched uplifts and in the third-groups of uplifts on the slope of large structures etc.

Taking into consideration extreme indefiniteness of this term understood and used quite often with a different meaning by various authors, including American geologists who have suggested it, we would esteem to abondon it.

The analysis of regularities in the occurence of presently known oil and gas accumulation zones proves these to be the elements of large downwarped areas in the actual structural pattern of the earth's crust. Regional hydrogeological investigations have proved that the relationship in the location of feeding and discharge areas within the rocks of high permeability determines the direction of water flow inside these rocks serving

as reservoirs for mobil substances. Water in its circulation is saturated to a certain extend with various salts and frequently with organic acids. The compositions of hydrocarbon compounds in small concentrations are frequently found to be dissolved in water. In the process of differentiation of mobil substances with the change in temperature and pressure the hydrocarbon compounds educe from water and are accumulated in the traps in the form of oil and gas pools provided the traps are available in reservoirs.

Formation and preservation of oil and gas accumulations in local traps are determined principally by regional hydrogeological environment. The occurence of numerous accumulations united into oil and gas accumulations zones is tightly related to the present features of structure of thick series of sediments inclosing the aforementioned accumulations. The regular relationship between the known zones of oil and gas accumulation and variously typed large downwarped regions of the present structural pattern of the earth's crust has served as a basis for considering such depressions as oil and gas basins (Brod, 1953 /1/). Each oil and gas basin is a vast artesian basin and the location of oil and gas accumulation zones within its confines reflects the stage of present equilibrium of fluids and gases saturating reservoir rocks under present structural pattern and regional hydrogeological environment.

Conditions of oil and gas accumulation and preservation of oil and gas pools should be examined independently for each oil and gas basin.

All known oil and gas basins according to their geotectonic nature and conditions of oil and gas accumulation are

divided by us into three ~~basic~~ main groups :

(1) Basins related to troughs of plain platform territories;

(2) Basins of intermontane troughs;

(3) Basins related to piedmont depressions of the young folded structures.

A thorough study of the conditions of formation of oil and gas accumulation zones is possible only in case we take into consideration all the changes undergone by a certain area of the earth's crust in the process of its geological history. Whether the correlation between reservoir rocks of high permeability and poorly permeable ones - pelite rocks - is most favourable for oil and gas accumulations - this factor can only be determined if an adequate knowledge is possessed of the regularities in the change of thicknesss and lithology of sedimentary series forming a basin. But, on the other hand, whatever changes has undergone in its geological past the area where is located presently a zone of oil and gas accumulation, the decisive factor determining its existence is the present location of the zone within the actual confines of downwarped region considered as oil and gas basin. Such a presumption is derived from the fact that the formation of elementary accumulations - oil and gas pools - which are parts of oil and gas accumulation zones, takes place in the process of migration and differentiation of mobil substances in highly permeable rocks serving as their natural reservoirs. Formation and preservation

of each and every elementary accumulation are possible only in the trap not allowing the escape of oil and gas. Preservation and refilling of oil and gas pools are possible only in case the traps remain intact till present time. Any change in trap forms and in conditions of regional hydrogeological environment leads to the destructions of pools or, at the best, to their redistribution.

The present oil and gas accumulations reflect actually existing equilibrium of mobil substances contained in oil and gas basins.

Rôle of different types of migration in the formation of oil and gas accumulations

Formation of separate pools as well as large oil and gas accumulation zones takes place in the process of migration and differentiation of the substances composing oil and gas.

The problem of migration has been studied by many researchers during the whole period of development of the science of petroleum. Summarized data, status of the problem and classification of migration processes have been published in the works of Lilley (1928), Krejci-Graf (1930), Gubkin (1932, 1937), Lahee (1934), Bloesch et al. (1936), Illing (1939,) 1946), Van Tuyl, Parker, Skuters (1945), Brod (1947, 1951, 1955 /2/, 1957 /1/), Zalicker (1949), Landes (1951), Vassoevich & Ouspenskiy (1954), Krems (1954), Gussow (1954, 1955) Bakirov (1955), Linetsky (1956), Sokolov (1956), Hobson (1956) and in many other books devoted to oil and gas geology.

An attempt to systematize all known data on migration of bituminous substances, gas, petroleum and its derivatives in thick series of sediments and in separate strata has been made by us after Illing, Lahee, Krejci-Graf and Bloesch in 1947-1951. This attempt has resulted in working out of a classification of migration processes according to distance and character of movement (fig.1) and according to ways and direction of movement (fig.2). The least studied remains to-day the problem of migration in source rocks of petroleum source material.

A slow molecular migration of loosely-bounded mobil substances is going on in subcapillary pores of pelite rocks. Among these substances water and bituminous substances interacting with it are of principal importance. The outcropping folded sedimentary series are feeded by atmospheric water and water flows. Water circulates in super-capillary pores along permeable carrier-beds serving as natural reservoirs for mobil substances. Water circulation is directed from uplifted areas of outcropping strata (feeding area) on their down-dip side. The speed of water circulation is not uniform in different sections of the flow.

Water in its circulation carries away the bituminous substances migrated from pelite rocks. The differentiation of mobil substances according to their specific gravity proceeds considerably easier in the process of movement. The hydrocarbon compounds educing from water and coming to its surface combine together and form oil and gas accumulations provided the traps are available.

Solubility of hydrocarbon compounds in water changes according to various correlations between hydrocarbons and depending on temperature and pressure. Water dissolving hydrocarbon compositions at certain temperatures and pressures may educe same in the process of movement into different environment. In such a way proceeds migration of bituminous substances when they are in dissolved (in water) state. Water may force bituminous substances out of fine pores into larger ones by capillary pressure. The mechanics of migration of hydrocarbon compounds under the action of capillary forces are not studied yet adequately. The value of capillary pressure depends on properties of mobil substances filling the pores, on properties of rock mineral matter and size of pores. The movement of bituminous substances under the action of capillary forces is always directed from fine pores towards the large ones. Since capillary forces in fine pores surpass considerably gravitative forces, the movement may go not only in upwards but also in lateral direction. We may surmise the movement of bituminous substances in fine pores as a movement in the form of molecular films.

Any movement (migration) of mobil substances, including bituminous substances, in subcapillary pores of source rocks can be considered as a molecular singenetic migration. The same movement in subcapillary pores of the strata outside of the source rock is epigenetic molecular migration.

The movement of mobil substances proceeding in super capillary pores and fissures can be considered as a free migration of water and hydrocarbon compounds related to it. The free

migration proceeds in accordance with the laws of percolation of mobil substances in super capillary pores of highly permeable rocks. Though, in contradistinction to molecular migration, in the process of free migration are moving considerable masses of substances, this very process, depending on its distance, may be either of local or wide regional importance.

Formation of a single oil field is related to local migration, viz. to migration of local importance. Under this term are understood the processes not overstepping the limits of a single structural element controlling the formation of a certain oil field consisting of several oil (gas) pools and, in a particular case, consisting of one pool only.

Regional migration is the process determining the formation of a group of oil fields regularly related to one or several oil and gas accumulation zones. The regional migration embracing large depressions can determine the formation of numerous oil and gas accumulation zones which are the elements of a single oil and gas basin.

According to the ways of movement any movement of mobil substances inside the rocks possessing supercapillary pores and fissures can be considered as intra-reservoir migration. The movement of mobil substances along subcapillary pores and gaping fissures of poorly permeable rocks separating natural reservoirs can be considered as extra-reservoir migration. In the process of both intra-

reservoir and extra-reservoir migration the movement of mobil substances can proceed in vertical and lateral direction.

Numerous publications are devoted to the study of forces which provoke intra-reservoir and extra-reservoir migration.

Any mobil substance which is contained in the pores of a sediment during sedimentation period should either enter in composition of the rock or migrate as soon as the sediments begin to compact. The movement of mobil substances in compacted sediments proceeds in the direction of reduced pressure. In the process of sediments compaction free water and substances related to it are carried away first of all. For bitumen formation and oil and gas accumulation is of principal importance the subsequent migration process accompanying compacting of the sediments towards their consolidation. The size of subcapillary pores constantly diminishes in the process of compacting of pelite rocks, which fact provokes a slow removal of loosely-bounded water. In all probability the most mobil organic compounds are removed at the same time.

It may be supposed that all main transformations of organic substances contained in pelite rocks take place in the process of migration in subcapillary pores, Simultaneously with compacting of pelite rocks goes on a slow metamorphism and dissociation of organic matter. Dissociation is accompanied apparently by disproportioning of hydrogene with educing, on the one hand, of more stable coaly compounds and, on the other hand, of mobil bituminous particles, which are moved away together with loosely-bounded water.

In the process of subcapillary migration takes place the change of main coaly part of dispersed organic substances towards coalification with the formation of graphite at the last stage of metamorphisation. The bituminous substances educed in the process of enrichment in hydrogene content should change from asphaltines and resins towards oils and up to methane. In all appearance the most mobil substances, after differentiation, are carried away together with portions of loosely-bounded water and migrate into reservoir rocks if such are available near by. Such is probably the inineral of migration of bituminous substances, first in the course of singenetic migration in subcapillary pores and later on in the course of free migration together with water in natural reservoirs towards a trap where proceeds the formation of oil (gas) pool. Formation of oil (gas) pool in natural reservoirs limited on all sides by the rocks of low permeability goes on mainly at the expense of migration of hydrocarbon compounds ~~out of~~ from subcapillary pores of pelite rocks into super-capillary pores of reservoir rocks. It should be noted that extra-reservoir migration of mobil substances in subcapillary pores is tightly connected with compacting of the rocks and exists apparently only until their lithification, viz. until the time the rocks did not lose their plastic property.

Free extra-reservoir migration through heterogeneous rocks series is related to migration of large masses of mobil substances from the areas of higher pressure along gaping fractures and fissures. Water masses may entrap in their

flow bituminous substances in gaseous and sometimes in liquid state and carry same from source rocks to overlying reservoir rocks.

The water movement is of principal importance for intra-reservoir migration of hydrocarbon compounds towards their accumulation in traps. Differentiation of mobil substances in natural reservoirs takes place in the process of migration of water and bituminous compounds dissolved therein. The emission of free gas and liquid oil may take place only in case of favourable conditions permitting their accumulation in a trap.

Thus on their way to formation of each pool the bituminous substances accomplish first a molecular migration in subcapillary pores and thereafter a free migration inside the natural reservoirs in the direction of a trap. The formation of an oil and gas pool is accomplished at the time of accumulation of hydrocarbon compounds in a trap.

As appears from the above the migration is one of the main processes of oil and gas formation as well as of their accumulation in the earth's crust, while oil and gas accumulation zones emerge in the process of different types of migration of mobil substances, as enumerated above.

Conclusions

In conclusion it should be noted that geologists, geochemists, physicists-chemists, mathematicians and physicists of the whole world have made enormous contribution towards the solution of the problem of formation of oil and gas accumulations.

This of course does not mean that all questions are solved, but, nevertheless, an enormous work has been done, as for a great number of large territories both geosynclinal and platform ones had been ascertained the rock series to which are regionally and genetically related oil and gas accumulations. We can discuss to-day in a most specific manner the geological and geochemical environment which illustrates the formation of these rock series inclosing oil and gas pools as well as tremendous quantities of dispersed organic substances. To-day are studied the petroleum, gas and water saturating natural reservoirs in which took place the formation of pools. Also are studied reservoir properties and mineralogical composition of the rocks forming the reservoirs as well as composition of low permeable rocks surrounding same. In the latter are studied the basic properties of dispersed organic substances and geochemical characteristics of the rocks.

The existence of free oil and gas in the form of pools in reservoir rocks forming natural receptacles is beyond any doubt. The free migration of water, oil and gas is ascertained by direct observations. As an exemple of such migration may be cited abundant oil and gas seepages known in mountain and piedmont regions throughout the Globe. This phenomenon is explained by the fact that in strongly disturbed regions there exist numerous ways - fissures and fractures - facilitating migration of oil and gas. In less disturbed regions lacking intensive oil and gas seepages migration of mobil substances in the subsurface goes on all

the same more or less actively. Migration and redistribution of mobil substances - gas, oil and water - inside natural reservoirs is proved by their regular, according to specific gravity, distribution in highly permeable strata separated by shales of low permeability. With this phenomenon is connected the regular relationship between oil and gas pools and traps, the latter in conjuction with local structural elements forming oil fields grouped into oil and gas accumulation zones.

In the frame work of the problem of formation of oil and gas accumulations one of the principal questions to be solved is the question of genetic kinship between oil and gas accumulated in traps and bituminous substances inclosed in subcapillary pores of the rocks considered as source rocks. For solution of this problem is necessary not only a thorough laboratory study of organic matter dispersed in the rocks, but also a study of its transformations. When carrying out such investigations it is required to reconstruct in the laboratory a simulated natural environment close to physico-chemical transformations undergoing by mobil bituminous substances, consisting of different compositions of asphaltines, resins and oils, in the course of their transference from dispersed molecular state in subcapillary pores of pelite rocks into super-capillary pores of reservoir rocks saturated with free water. Notwithstanding a number of similar features the light bituminous substances extracted from pelite rocks differ from the oil forming pools in reservoir rocks. And

this is quite natural as physico-chemical transformations of the substances proceed in a different way in subcapillary pores of pelite rocks and in super-capillary pores of reservoir rocks. Therefore, the petroleum which is known to us as a comparatively homogeneous mass saturating well permeable porous and fractured rocks is in general similar to bituminous substances dispersed in pelite rocks, but at the same time is distinguished from them by a number of specific features. Apparently the existence of petroleum as a definite form of a mass composition of hydrocarbon compounds is appropriate only to the rocks permitting a free migration and differentiation of fluids and gases. All previous attempts to outline chemical transformation of organic substances into petroleum did not take into consideration the fact that in the course of migration of hydrocarbon compounds dispersed in subcapillary pores of silt sediments into highly permeable porous rocks not only a quantitative but also a qualitative change of the substance is taking place. This is a physico-chemical process and its cognizance requires a number of extensive laboratory experiments.

There is notable difference of opinion in the interpretation of the process of migration of bituminous substances jointly with water inside natural reservoirs. Scale and mechanics of this phenomenon are open for discussion. It is not clear in what physical conditions migrate hydrocarbon compounds jointly with water in the direction of traps in which oil and gas pools are formed.

Are also widely discussed the processes of physico-chemical transformations of the oils due to the changes in temperature and pressure in the course of geological events undergone by the earth's crust area to which are related oil and gas accumulations.

In the light of formulated views concerning oil and gas accumulation zones considered to be the elements of large downwarped areas of the actual structural pattern of the earth's crust, we are confronted with the question whether presently known oil and gas accumulations are of the same age as the traps containing same. In this connection it is extremely important to ascertain the age of formation of oils and gases constituting the pools.

Notwithstanding the fact that many problems remain so far unsolved, the above general outline provides a possibility to formulate the fundamental condition of oil and gas accumulation in the earth's crust determining the methods of exploratory-prospecting work and comparative estimation of oil and gas possibilities of large territories.

This fundamental condition is a lengthy and stable subsidence of the earth's crust area under study in which area subsiding trend and that of burial of the sediments predominate over ascending trend in the process of small and large oscillating movements of the earth's crust (Brod - 1947, 1951). Only subsidence of sediment on a considerable depth and its overlying by poorly permeable deposits may assure preservation of organic matter in the subsurface and its dissociation with formation of new portions of mobil

bitumens. Subsidence preserves the originated hydrocarbons from dispersion in water basins. In all transformations only a certain part of organic matter buried in sediments is transformed into hydrocarbon compounds and under favourable conditions may form oil and gas pools. Greater quantity of organic matter in the form of dispersed coaly particles is preserved in the rocks and can be easily revealed by proper investigations.

Therefore, the hydrocarbon compounds originating the petroleum emerge in the process of struggle of two opposed tendencies with predominence of subsiding (descending) trend over ascending trend in the course of small and large oscillating movements of the earth's crust area under study.

Should source rock formations contain beds and lenses of sand or other highly permeable strata, the migration of mobil substances from pelite rocks into well permeable reservoir rocks goes on with the subsiding of the whole sedimentary rock series. The reservoir rocks under loading effect of overlaying strata are compacted in lesser degree than pelite rocks. The mobil bituminous substances migrating from sub-capillary pores in super-capillary pores and fissures of reservoir rocks become apparently dissolved in water and migrate together with it. In the course of this migration the differentiation of mobil substances inside the natural reservoirs is taking place.

In natural reservoirs surrounded on all sides by pelite rocks the hydrocarbon compounds fill gradually a trap and may

[illegible] oil (gas) pool closed on all sides. In case of [illegible] of natural reservoirs within a large strike the hydrocarbon compounds emanating from water are accumulated in various structural bendings of the strata, in wedging out zones or in zones of unconformable overlapping of the strata and in all other areas of natural reservoirs which may serve as traps.

With subsiding (descending) trend emerging victories over ascending trend the oil and gas pools formed in traps are found to be buried in subsurface. This process is favourable so far as the pools are not subjected to high temperatures and pressures liable to destroy and disperse the oil.

Therefore, the victory of subsiding (descending) trend over ascending trend in the course of small and large oscillating movements of the upper parts of the earth's crust is a fundamental condition of both - oil and gas formation and oil and gas accumulation.

This condition, which may be considered as a fundamental principle of oil and gas accumulation in the earth's crust, should serve as a chief criterion when estimating oil and gas possibilities of large territories.

I.O.Brod.

Moscow, April-May, 1957.

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CLASSIFICATION OF MIGRATION PROCESSES ACCORDING TO WAYS OF MOVEMENT

Group	Extra-Reservoir Migration (in poorly permeable rocks)		Intra-Reservoir Migration (in highly permeable rocks)	
In relation to rock series in which migration takes place	Singenetic (in sediment where accumulation and transformation of organic substances take place)	Epigenetic (through heterogeneous thick rock series)	Intra-strata	Within thick series of sediments consisting of many highly permeable strata
According to type of way of movement	Along subcapillary pores (subcapillary)	Along capillary pores (capillary)	Porous	
		Along fractures and fissures (fissured)	Fissured	
According to direction of movement	Lateral			
	Vertical			

CLASSIFICATION OF MIGRATION PROCCESSES ACCORDING TO CHARACTER AND DISTANCE OF MOVEMENT

Main groups of migration processes according to distance of movement	Main types of migration according to character of movement	Molecular (diffusive-film) migration / Free migration
Local Migration	Controlled by structural features	In the confines of separate structural uplifts
		In connection with local faults on monoclines and homoclines
	Controlled by stratigraphical features	In connection with local lithological changes of the rocks
		Along the surface of discordance provoked by local stratigraphic unconformity
Regional Migration	Controlled by structural features	In connection with regional dip of strata
		In connection with anticlinal zones of regional importance
		In connection with regional fractures
	Controlled by stratigraphical features	Along the surface of discordance provoked by regional stratigraphic unconformity
		In connection with zones featured by regional change of facies